

CLAIMS:

1. A method of operating an image processing apparatus for processing image data representing images of an object taken from a plurality of different camera positions, the method comprising the steps of:
- 5 (a) determining the viewing volume for each camera position;
- (b) determining the volume bounded by the intersection of the viewing volumes; and
- 10 (c) setting the bounded volume as an initial space for use in deriving a representation of a three-dimensional surface of the object using said images.
- 15 2. A method according to claim 1, further comprising the step (d) of dividing the bounded volume into voxels to form an initial voxel space.
3. A method according to claim 2, further comprising:
- 20 (e) determining, for each voxel that is not occluded by another voxel, the area corresponding to that voxel in each image in which that voxel is visible;
- (f) comparing characteristics of each of the image areas corresponding to the same voxel;

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(h) repeating steps (e) to (g) until all non-occluded voxels having inconsistent characteristics have been removed.

(e) comparing characteristics of each of the image
25 areas corresponding to the same voxel;

(f) removing a voxel in response to the characteristics of the image areas corresponding to that voxel being inconsistent; and

(g) repeating steps (d) to (f) until all non-
5 occluded voxels having inconsistent characteristics have been removed.

5. A method according to claim 1, wherein the step of
10 determining the viewing volume for a camera position comprises determining the viewing volume using data representing a camera focal point and a camera imaging area for that camera position.

6. A method according to claim 5, wherein the step of
15 determining the viewing volume includes projecting straight lines from the focal point through points on the boundary of the imaging area.

7. A method according to claim 1, wherein the step of
20 defining the intersection of the viewing volumes comprises (i) determining an initial intersection of the viewing volumes of first and second camera positions, (ii) determining the intersection of that intersection with another viewing volume and setting that intersection
25 as the current intersection and (iii) repeating steps (i)

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8. In an image processing apparatus having a processor
5 for processing image data representing images of an
object taken from a plurality of different camera
positions, a method of processing image data to derive a
representation of a three-dimensional surface of the
object, the method comprising the steps of:

(b) accessing data representing a first set of images of the object each recorded at a different camera position with respect to the object;

(d) comparing characteristics of each of the image areas corresponding to the same voxel;

20 areas corresponding to the same voxel;

(e) removing a voxel in response to the characteristics of the image areas corresponding to that voxel being inconsistent thereby producing a smaller voxel volume;

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the first set of images;

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producing a smaller voxel space;

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5 10. A method according to claim 8 or 9, which further comprises discarding the first set of images after step (f).

10 carrying out steps (g) to (j) by:

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step (g):
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to that voxel in each of the further images at step (h);

comparing the characteristics of the image areas of
the further images with the characteristic already

removing a voxel in response to an inconsistency in the compared characteristics thereby producing a smaller voxel space at step (j).

12. In an image processing apparatus having a processor for processing image data representing images of an object taken from a plurality of different camera positions, a method of processing image data to derive a representation of a three-dimensional surface of the object, the method comprising the steps of:

(a) defining a volume containing the object as an initial voxel space formed of voxels;

(b) accessing data representing a first set of images of the object each recorded at a different camera position with respect to the object;

(c) determining, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image of the first set of images in which that voxel is visible;

(d) comparing characteristics of each of the image areas corresponding to the same voxel;

(e) removing a voxel in response to the characteristics of the image areas corresponding to that voxel being inconsistent, thereby producing a smaller voxel volume;

(f) repeating steps (c) to (e) until all non-occluded voxels having inconsistent characteristics have been removed and storing the resulting voxel space as a representation of the three-dimensional object surface,

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together with the characteristic associated with each non-occluded voxel of the resulting voxel space;

(g) accessing data representing a second set of images consisting of a sub-set of the first set and a further image of the object recorded at a different camera position from the first set of images;

(h) determining, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each of the second set of images;

(i) comparing the characteristics of the image areas in each of the second set of images;

(j) removing a voxel in response to an inconsistency in the compared characteristics, thereby producing a smaller voxel space;

(k) repeating steps (h) to (j) until all non-occluded voxels having inconsistent characteristics have been removed and storing the resulting voxel space as a modified representation of the three-dimensional object surface.

13. A method according to claim 12, which further comprises repeating steps (g) to (k) for each of a series of further images and changing the second set of images accessed in step (g) with each repetition.

5 15. A method according to claim 13, which comprises changing the second set of images at each repetition by discarding at least one of the sub-set of the first set and including in the second set the further image accessed at the previous step (g).

16. In an image processing apparatus having a processor for processing image data representing images of an object taken from a plurality of different camera positions, a method of processing image data to derive a representation of a three-dimensional surface of the object, the method comprising the steps of:

(a) defining an initial volume containing the object surface as an initial space formed of voxels;

20 (b) accessing data representing images of the
object recorded at different camera positions with
respect to the object;

(c) checking to see if a voxel meets at least one criterion by projecting that voxel into at least one of the images;

25 (d) if the voxel does not meet said at least one

(e) then checking to see if the subsidiary voxels meets at least one criterion by projecting the subsidiary voxels into at least one of the images.

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17. A method according to claim 16, further comprising deciding that a sub-voxel does not form part of the three-dimensional surface and so should be removed if the sub-voxel does not meets said at least one criterion.

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18. A method according to claim 16, further comprising repeating steps c, d and e for any sub-voxel that does not meet said at least one criterion.

15 19. A method according to claim 16, wherein the at least one criterion comprises any one or more of the following:

1) the colour variance in a pixel patch to which the voxel projects in an image has a value lower than a predetermined value;

20 2) the difference in colour or average colour between pixel patches to which the voxel projects in different images has a standard deviation less than a predetermined value; and

3) the voxel is not partially occluded by a voxel
25 or subsidiary voxels of smaller size than the voxel.

20. In an image processing apparatus having a processor for processing image data representing images of an object taken from a plurality of different camera positions, a method of processing image data to derive a representation of a three-dimensional surface of the object, the method comprising the steps of:

- (a) defining an initial volume containing the object surface as an initial space formed of voxels;
- (b) accessing data representing images of the object recorded at different camera positions with respect to the object;
- (c) determining the area corresponding to a given voxel in each image in which the voxel is visible;
- (d) comparing characteristics of each of the image areas corresponding to the given voxel;
- (e) deriving from the compared characteristics a value representing the degree of any inconsistency between the characteristics of the image areas corresponding to the given voxel.
- (f) sub-dividing a voxel into subsidiary voxels in response to the derived value exceeding a threshold value and repeating steps (c) to (e) for each subsidiary voxel.

21. A method according to claim 20, further comprising:

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object surface as an initial space formed of voxels;

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respect to the object which data provides a colour value for each pixel of each image;

(c) determining the area corresponding to a voxel in each image in which the voxel is visible;

5 (d) determining a colour space value for each pixel of each area where each colour space value encompasses a range of pixel colour values;

(e) comparing the colour space values for each of the image areas corresponding to the same voxel; and

10 (f) removing the voxel only if the image areas do not share at least one colour space value.

24. In an image processing apparatus having a processor for processing image data representing images of an
15 object taken from a plurality of different camera positions, a method of processing image data to derive a representation of a three-dimensional surface of the object, the method comprising the steps of:

(a) defining an initial volume containing the
20 object surface as an initial space formed of voxels;

(b) determining the area corresponding to a voxel in each image in which that voxel is visible;

(c) comparing characteristics of each of the image areas corresponding to the voxel; and when the derived
25 value for a voxel exceeds a threshold value:

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(i) sub-dividing the voxel into subsidiary voxels;

(ii) determining the region corresponding to each sub-voxel in each image in which that sub-voxel is visible;

(iii) comparing characteristics of the image regions; and

(iv) removing the voxel only if there is no set of regions which contains a region from each image and for which the characteristics are not inconsistent.

25. A method according to of claim 4, wherein the step of determining the area corresponding to a voxel in an image comprises projecting the voxel into each image.

26. A method according to claim 4, wherein the step of comparing characteristics of the image areas or regions comprises comparing colours of the image areas or regions.

27. A method according to claim 4, which further comprises outputting a signal carrying data defining the initial space or the voxel representation of the three-dimensional object surface.

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32. Apparatus according to claim 31, further comprising processor means operable:

5 (i) to determine, for each voxel that is not occluded by another voxel, the area corresponding to that voxel in each image in which that voxel is visible;

(ii) to compare characteristics of each of the image areas corresponding to the same voxel; and

10 (iii) to remove each non-occluded voxel having inconsistent image area characteristics so as to provide a representation of the three-dimensional object surface.

33. An image processing apparatus for processing image data representing images of an object taken from a plurality of different camera positions to derive a
15 representation of a three-dimensional surface of the object, the apparatus comprising:

means for determining the viewing volume for each camera position at which an image was taken;

20 means for determining the volume bounded by the intersection of the viewing volumes;

means for dividing the bounded volume into voxels to form an initial voxel space; and

processor means operable:

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(ii) to compare characteristics of each of the image
5 areas corresponding to the same voxel; and

10 34. Apparatus according to claim 30, wherein the means for determining the viewing volume for a camera position is arranged to determine the viewing volume using data representing a camera focal point and camera imaging area for that camera position.

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with another viewing volume and to set that intersection as the current intersection and (iii) to repeat (i) and (ii) until the viewing volumes for all camera positions have been considered.

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37. An image processing apparatus for processing image data representing images of an object taken from a plurality of different camera positions to derive a representation of a three-dimensional surface of the object, the apparatus comprising:

means for defining an initial volume containing the object as an initial space formed of voxels, and processor means operable:

(i) to access data representing a first set of images of the object each recorded at a respective one of a number of different camera positions with respect to the object;

(ii) to determine, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image of the first set of images in which that voxel is visible;

(iii) to compare characteristics of each of the image areas corresponding to the same voxel to remove any voxel have inconsistent characteristics and to store the resulting voxel space as a representation of the three-

dimensional object surface, together with the characteristic associated with each non-occluded voxel of the resulting voxel space;

(iv) then to access data representing a further
5 image of the object recorded at a different camera position from the first set of images;

(v) to determine, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in the further image;

10 (vi) to compare the characteristic of the image area in the further image with the characteristic already associated with that voxel;

(vii) to remove any voxel for which the characteristic of the image area of the further image is
15 inconsistent with that already associated with that voxel; and

(viii) to store the resulting voxel space as modified representation of the three-dimensional object surface.

20 38. An apparatus according to claim 37 wherein the processor means is operable to carry out steps (iv) to (viii) for each of a series of further images.

39. An apparatus according to claim 37, wherein the
25 processor means is operable to cause the first set of

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images to be discarded after the processor means has stored the resulting voxel space.

40. An apparatus according to claim 37, wherein the
5 processor means is operable to access data representing a plurality of further images and to carry out steps (iv) to (viii) using all of the further images.

41. An image processing apparatus for processing image
10 data representing images of an object taken from a plurality of different camera positions to derive a representation of a three-dimensional surface of the object, the apparatus comprising:

means for defining an initial volume containing the
15 object as an initial voxel space formed of voxels; and
processor means operable:

(i) to access data representing a first set of
images of the object each recorded at a respective
different one of a number of different camera positions
20 with respect to the object;

(ii) to determine, for each voxel of the voxel space
that is not occluded by another voxel, the area
corresponding to that voxel in each image of the first
set of images in which that voxel is visible;

(iii) to compare characteristics of each of the image areas corresponding to the same voxel;

(iv) to remove any voxel having inconsistent characteristics and to store the resulting voxel space as
5 a representation of the three-dimensional object surface, together with the characteristic associated with each non-occluded voxel of the resulting voxel space;

(v) then to access data representing a second set of images consisting of a sub-set of the first set and a
10 further image of the object recorded at a different camera position from the first set of images;

(vi) to determine, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image of the second
15 set;

(vii) to compare the characteristics of the image areas of second set;

(viii) to remove any voxel having inconsistent characteristics in the second set of images to store the
20 resulting voxel space as an updated representation of the three-dimensional object surface.

42. Apparatus according to claim 41, wherein the processor means is operable repeat steps (v) to (viii)
25 for each of a series of different sets of images.

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43. Apparatus according to claim 42, wherein the processor means is operable to change the second set of images at each repetition by adding a further image not forming part of the first set of images.

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44. Apparatus according to claim 42, wherein the processor means is operable to change the second set of images at each repetition by discarding at least one of the sub-set of the first set of images and to include in
10 the second set at least one newly accessed further image.

45. In an image processing apparatus for processing image data representing images of an object taken from a plurality of different camera positions to derive a
15 representation of a three-dimensional surface of the object, the apparatus comprising:

means for defining an initial volume containing the object surface as an initial space formed of voxels;

means for accessing data representing images of the
20 object recorded at different camera positions with respect to the object; and

processor means operable:

(c) to check to see if a voxel meets at least one criterion by projecting that voxel into at least one of
25 the images;

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(d) if the voxel does not meet said at least one criterion, to divide the voxel into subsidiary voxels; and

5 (e) then to check to see if the subsidiary voxels meets at least one criterion by projecting the subsidiary voxels into at least one of the images.

46. Apparatus according to claim 45, wherein the processor means is operable to decide that a sub-voxel
10 does not form part of the three-dimensional surface and so should be removed if the sub-voxel does not meets said at least one criterion.

47. Apparatus according to claim 45, wherein the
15 processor means is operable to repeat c, d and e for any sub-voxel that does not meet said at least one criterion.

48. Apparatus according to claim 45, wherein the at least one criterion comprises any one or more of the
20 following:

4) the colour variance in a pixel patch to which the voxel projects in an image has a value lower than a predetermined value;

5) the difference in colour or average colour

between pixel patches to which the voxel projects in different images has a standard deviation less than a predetermined value; and

- 6) the voxel is not partially occluded by a voxel
5 or subsidiary voxels of smaller size than the voxel.

49. An image processing apparatus for processing image data representing images of an object taken from a plurality of different camera positions to derive a
10 representation of a three-dimensional surface of the object, the apparatus comprising:

means for defining an initial volume containing the object surface as an initial space formed of voxels;

means for accessing data representing images of the
15 object recorded at different camera positions with respect to the object; and

processor means operable:

- (i) to determine the area corresponding to a given voxel in each image in which the voxel is visible;
20 (ii) to compare characteristics of each of the image areas corresponding to the given voxel;
(iii) to derive from the compared characteristics a value representing the degree of any inconsistency between the characteristics of the image areas
25 corresponding to the given voxel;

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(iv) to sub-divide a voxel into subsidiary voxels in response to the derived value exceeding a threshold value and to repeat steps (i) to (iii) for each subsidiary voxel;

5 (v) in response to a subsidiary voxel having a derived value exceeding a threshold value and a size greater than a minimum size, to sub-divide that subsidiary voxel into subsidiary voxels and to repeat (i) to (iii) for each subsidiary voxel of that subsidiary
10 voxel;

(vi) to remove any subsidiary voxel of the minimum size having a derived value exceeding the threshold value; and

(vii) to repeat (i) to (vi) for each voxel that is
15 not occluded by another voxel to provide a representation of the three-dimensional object surface consisting of the remaining non-occluded voxels and subsidiary voxels.

50. Apparatus according to claim 49, wherein the
20 processor means is operable to repeat (i) to (vi) until the degree of inconsistency for all non-occluded voxels is below a predetermined value.

51. An image processing apparatus for processing image
25 data representing images of an object taken from a

means for defining an initial volume containing the
5 object surface as an initial space formed of voxels;

10 processor means operable:

(b) to determine a colour space value for each pixel of each area where each colour space value encompasses a range of pixel colour values;

(d) to remove the voxel only if the image areas do not share at least one colour space value.

52. An image processing apparatus for processing image data representing images of an object taken from a plurality of different camera positions, a method of processing image data to derive a representation of a

three-dimensional surface of the object, the apparatus comprising:

means for defining an initial volume containing the object surface as an initial space formed of voxels;

5 means for accessing data representing images of the object recorded at different camera positions with respect to the object; and
processor means operable:

(a) to determine the area corresponding to a voxel
10 in each image in which that voxel is visible;

(b) to compare characteristics of each of the image areas corresponding to the same voxel; and

(c) to derive from the compared characteristics a value representing the degree of any inconsistency
15 between the characteristics of the image areas corresponding to the voxel and, when the derived value for a voxel exceeds a threshold value,

(i) to sub-divide the voxel into subsidiary voxels,

20 (ii) to determine the region corresponding to each sub-voxel in each image in which that sub-voxel is visible,

(iii) to compare characteristics of the image regions, and

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(iv) to remove the voxel only if there is no set of regions which contains a region from each image and for which the characteristics are not inconsistent.

5 53. Apparatus according to claim 30, wherein the processor means is operable to determine, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image in which that voxel is represented or visible by projecting
10 the voxel into the image.

54. Apparatus according to claim 30, wherein the processor means is operable to compare characteristics of each of the image areas corresponding to the same voxel
15 by comparing the colours of each of the image areas.

55. Apparatus according to claim 30, further comprising means for outputting a signal carrying data defining the initial space or the voxel representation of the three-
20 dimensional object surface.

56. Apparatus according to claim 30, further comprising means for providing a computer storage medium storing data defining the initial space or the voxel
25 representation of the three-dimensional object surface.

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57. Apparatus according to claim 30, further comparing means for generating texture data for rendering onto a representation of the three-dimensional object surface.

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5 58. A method according to claim 16, which further comprises:

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accessing data representing a further image of the object recorded at different camera position; and then repeating steps of ^{claim 16} ~~any one of claims 16 to 23~~ using that further image.

59. A method according to claim 16, which further comprises:

accessing data representing a set of images consisting of a sub-set of the images accessed at step (b) and a further image of the object recorded at a different camera position;

^{claim 16}
repeating steps of ~~any one of claims 16 to 23~~ using that set of images.

60. A method according to claim 8, which comprises defining the initial space using a method as set out in claim 1.

61. Apparatus according to claim 48, wherein the processor means is also operable:

a 5 to repeat steps set out in ^{claim 48}~~any one of claims 48 to 52~~ using that further image.

62. Apparatus according to claim 48, wherein the processor means is also operable:

10 to access data representing a set of images consisting of a sub-set of images previously accessed and a further image of the object recorded at a different camera position and then to repeat steps set out in ^{claim 48}~~any one of claims 48 to 52~~ using that set of images.

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63. Apparatus according to claim 48, wherein the processor means is operable to define the initial space as set out in any one of claim 30.

20 64. A storage medium carrying processor implementable instructions for causing processing means to carry out a method in accordance with claim 1.

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65. A signal carrying processor implementable instructions for causing processing means to carry out a method in accordance with claim 1.

5 66. A storage medium carrying processor implementable instructions for causing processing means to become configured to form apparatus in accordance with claim 30.

10 67. A signal carrying processor implementable instructions for causing processing means to become configured to form apparatus in accordance with any one of claim 30.

15 68. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and using the images and the camera positions to generate the three-dimensional computer model, a method of processing
20 the image data to derive a computer representation of a three-dimensional surface of the object, the method comprising the steps of:

(a) determining the viewing volume for each camera position at which an image was taken;

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(b) determining the volume bounded by the intersection of the viewing volumes;

(c) defining the bounded volume as an initial voxel space formed of voxels;

5 (d) determining, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image in which that voxel is shown;

10 (e) comparing characteristics of each of the image areas corresponding to the same voxel;

(f) removing a voxel in response to the characteristics of the image areas corresponding to that voxel being inconsistent; and

15 (g) repeating steps (d) to (f) until all non-occluded voxels having inconsistent characteristics have been removed.

69. In a method of processing image data defining images of an object to generate a three-dimensional computer
20 model of the object by determining camera positions at which the images were recorded and using the images and camera positions to generate the three-dimensional computer model, an improvement comprising processing the image data to derive a computer representation of a
25 three-dimensional surface of the object by:

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(b) determining the volume bounded by the intersection of the viewing volumes;

(d) determining, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image in which that voxel is shown;

(f) removing a voxel in response to the characteristics of the image areas corresponding to that voxel being inconsistent; and

(g) repeating steps (d) to (f) until all non-occluded voxels having inconsistent characteristics have been removed.

70. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and by using the images and the camera positions to generate the three-dimensional computer model, apparatus for

processing the image data to derive a computer representation of a three-dimensional surface of the object, the apparatus comprising:

5 a processor configured by processor instructions to operate:

to determine the viewing volume for each camera position at which an image was taken;

to determine the volume bounded by the intersection of the viewing volumes;

10 to divide the bounded volume into voxels to form an initial voxel space;

to determine for a voxel that is not occluded by another voxel, the area corresponding to that voxel in each image in which that voxel is represented;

15 to compare characteristics of each of the image areas corresponding to the same voxel; and

remove a voxel when the characteristics of the image areas corresponding to that voxel are inconsistent.

20 71. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and by using the images and the camera positions to generate the
25 three-dimensional computer model, an improvement

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comprising apparatus for processing the image data to derive a computer representation of a three-dimensional surface of the object, the apparatus comprising a processor configured by processor instructions to
5 operate:

to determine the viewing volume for each camera position at which an image was taken;

to determine the volume bounded by the intersection of the viewing volumes;

10 to divide the bounded volume into voxels to form an initial voxel space;

to determine, for a voxel that is not occluded by another voxel, the area corresponding to that voxel in each image in which that voxel is represented;

15 to compare characteristics of each of the image areas corresponding to the same voxel; and

to remove a voxel when the characteristics of the image areas corresponding to that voxel are inconsistent.

20 72. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and using the images and the camera positions to generate the
25 three-dimensional computer model, a method of processing

the image data to derive a representation of a three-dimensional surface of the object, the method comprising the steps of:

5 (a) defining a volume containing the object as an initial space formed of voxels;

(b) accessing data representing a first set of images of the object each recorded at a different camera position with respect to the object;

10 (c) determining, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image of the first set of images in which that voxel is visible;

(d) comparing characteristics of each of the image areas corresponding to the same voxel;

15 (e) removing a voxel in response to the characteristics of the image areas corresponding to that voxel being inconsistent thereby producing a smaller voxel volume;

20 (g) accessing data representing a further image of the object recorded at a different camera position from the first set of images;

(h) determining, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in the further image;

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(i) comparing the characteristic of the image area of the further image with the characteristic already associated with that voxel; and

(j) removing a voxel in response to an inconsistency in the characteristics compared at step (i), thereby producing a smaller voxel space.

73. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and using the images and the camera positions to generate the three-dimensional computer model, a method of processing the image data to derive a computer representation of a three-dimensional surface of the object, the method comprising the steps of:

(a) defining a volume containing the object as an initial space formed of voxels;

(b) accessing data representing a first set of images of the object each recorded at a different camera position with respect to the object;

(c) determining, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image of the first set of images in which that voxel is visible;

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(e) removing a voxel in response to the characteristics of the image areas corresponding to that voxel being inconsistent, thereby producing a smaller voxel volume;

(h) determining, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each of the second set of images;

(j) removing a voxel in response to an inconsistency in the characteristics compared at step (i), thereby producing a smaller voxel space.

74. In a method of processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and using the images and the camera positions to generate the three-dimensional

(a) defining a volume containing the object as an
5 initial space formed of voxels;

(c) determining, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image of the first set of images in which that voxel is visible;

15 (e) removing a voxel in response to the characteristics of the image areas corresponding to that voxel being inconsistent thereby producing a smaller voxel volume;

(h) determining, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in the further image;

(j) removing a voxel in response to an inconsistency in the characteristics compared at step (i), thereby producing a smaller voxel space.

(c) determining, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image of the first set of images in which that voxel is visible;

(d) comparing characteristics of each of the image areas corresponding to the same voxel;

(e) removing a voxel in response to the characteristics of the image areas corresponding to that voxel being inconsistent thereby producing a smaller voxel volume;

(g) accessing data representing a second set of images consisting of a sub-set of the first set and at least one further image of the object recorded at a different camera position from the first set of images;

(h) determining, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each of the second set of images;

(i) comparing the characteristics of the image areas in each of the second set of images; and

(j) removing a voxel in response to an inconsistency in the characteristics compared at step (i), thereby producing a smaller voxel space.

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76. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and by using the images and the camera positions to generate the

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1997-1998		1998-1999		1999-2000		2000-2001		2001-2002		2002-2003		2003-2004		2004-2005		2005-2006		2006-2007		2007-2008		2008-2009		2009-2010		2010-2011		2011-2012		2012-2013		2013-2014		2014-2015		2015-2016		2016-2017		2017-2018		2018-2019		2019-2020		2020-2021		2021-2022		2022-2023		2023-2024		2024-2025		2025-2026		2026-2027		2027-2028		2028-2029		2029-2030		2030-2031		2031-2032		2032-2033		2033-2034		2034-2035		2035-2036		2036-2037		2037-2038		2038-2039		2039-2040		2040-2041		2041-2042		2042-2043		2043-2044		2044-2045		2045-2046		2046-2047		2047-2048		2048-2049		2049-2050		2050-2051		2051-2052		2052-2053		2053-2054		2054-2055		2055-2056		2056-2057		2057-2058		2058-2059		2059-2060		2060-2061		2061-2062		2062-2063		2063-2064		2064-2065		2065-2066		2066-2067		2067-2068		2068-2069		2069-2070		2070-2071		2071-2072		2072-2073		2073-2074		2074-2075		2075-2076		2076-2077		2077-2078		2078-2079		2079-2080		2080-2081		2081-2082		2082-2083		2083-2084		2084-2085		2085-2086		2086-2087		2087-2088		2088-2089		2089-2090		2090-2091		2091-2092		2092-2093		2093-2094		2094-2095		2095-2096		2096-2097		2097-2098		2098-2099		2099-2100		2100-2101		2101-2102		2102-2103		2103-2104		2104-2105		2105-2106		2106-2107		2107-2108		2108-2109		2109-2110		2110-2111		2111-2112		2112-2113		2113-2114		2114-2115		2115-2116		2116-2117		2117-2118		2118-2119		2119-2120		2120-2121		2121-2122		2122-2123		2123-2124		2124-2125		2125-2126		2126-2127		2127-2128		2128-2129		2129-2130		2130-2131		2131-2132		2132-2133		2133-2134		2134-2135		2135-2136		2136-2137		2137-2138		2138-2139		2139-2140		2140-2141		2141-2142		2142-2143		2143-2144		2144-2145		2145-2146		2146-2147		2147-2148		2148-2149		2149-2150		2150-2151		2151-2152		2152-2153		2153-2154		2154-2155		2155-2156		2156-2157		2157-2158		2158-2159		2159-2160		2160-2161		2161-2162		2162-2163		2163-2164		2164-2165		2165-2166		2166-2167		2167-2168		2168-2169		2169-2170		2170-2171		2171-2172		2172-2173		2173-2174		2174-2175		2175-2176		2176-2177		2177-2178		2178-2179		2179-2180		2180-2181		2181-2182		2182-2183		2183-2184		2184-2185		2185-2186		2186-2187		2187-2188		2188-2189		2189-2190		2190-2191		2191-2192		2192-2193		2193-2194		2194-2195		2195-2196		2196-2197		2197-2198		2198-2199		2199-2200		2200-2201		2201-2202		2202-2203		2203-2204		2204-2205		2205-2206		2206-2207		2207-2208		2208-2209		2209-2210		2210-2211		2211-2212		2212-2213		2213-2214		2214-2215		2215-2216		2216-2217		2217-2218		2218-2219		2219-2220		2220-2221		2221-2222		2222-2223		2223-2224	
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5 a processor configured by processor instructions to
operate:

(a) to define a volume containing the object as an initial space formed of voxels;

(b) to access data representing a first set of
10 images of the object each recorded at a different camera
position with respect to the object;

(c) to determine for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image of the first set of images in which that voxel is visible;

(d) to compare characteristics of each of the image areas corresponding to the same voxel;

(e) to remove a voxel in response to the characteristics of the image areas corresponding to that voxel being inconsistent thereby producing a smaller voxel volume;

(g) to access data representing a further image of the object recorded at a different camera position from the first set of images;

(i) to compare the characteristic of the image area
5 of the further image with the characteristic already
associated with that voxel;

10 (1) to store the resulting voxel space as an
modified representation of the three-dimensional object
surface.

77. In an image processing system for processing image
15 data defining images of an object to generate a three-
dimensional computer model of the object by determining
camera positions at which the images were recorded and by
using the images and the camera positions to generate the
three-dimensional computer model, apparatus for
20 processing the image data to derive a computer
representation of a three-dimensional surface of the
object, the apparatus comprising:

a processor configured by processor instructions to operate:

Figure 1 consists of ten panels (a-j) showing the effect of the 1997-1998 El Niño on the growth of 1000-year-old trees in the Amazon. The panels are arranged in two columns of five. Each panel shows a bar chart of growth rates (mm year⁻¹) for 1997-1998 and 1998-1999. The y-axis represents the growth rate, and the x-axis represents the year. The bars are labeled with the year and the growth rate. The growth rate for 1997-1998 is generally higher than for 1998-1999, indicating a decrease in growth rate during the El Niño event. The panels show the growth rate for different tree species and different locations in the Amazon. The growth rate for 1997-1998 is generally higher than for 1998-1999, indicating a decrease in growth rate during the El Niño event. The panels show the growth rate for different tree species and different locations in the Amazon.

(a) to define a volume containing the object as an initial voxel space formed of voxels;

(b) to access data representing a first set of images of the object each recorded at a different camera position with respect to the object;

(c) to determine, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image of the first set of images in which that voxel is visible;

(d) to compare characteristics of each of the image areas corresponding to the same voxel;

(e) to remove a voxel in response to the characteristics of the image areas corresponding to that voxel being inconsistent thereby producing a smaller voxel volume;

(g) to access data representing a second set of images consisting of a sub-set of the first set and a further image of the object recorded at a different camera position from the first set of images;

(h) to determine, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each of the second set of images;

(i) to compare the characteristics of the image areas in each of the second set of images;

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(1) to store the resulting voxel space as an
5 updated representation of the three-dimensional object
surface.

a processor configured by processor instructions to operate;

(b) to access data representing a first set of images of the object each recorded at a different camera position with respect to the object;

(c) to determine for each voxel of the voxel space
25 that is not occluded by another voxel, the area

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(1) to store the resulting voxel space as an modified representation of the three-dimensional object surface.

79. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and by
5 using the images and the camera positions to generate the three-dimensional computer model, an improvement comprising apparatus for processing the image data to derive a computer representation of a three-dimensional surface of the object, the apparatus comprising:

10 a processor configured by processor instructions to operate:

(a) to define a volume containing the object as an initial voxel space formed of voxels;

15 (b) to access data representing a first set of images of the object each recorded at a different camera position with respect to the object;

(c) to determine, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image of the first
20 set of images in which that voxel is visible;

(d) to compare characteristics of each of the image areas corresponding to the same voxel;

(e) to remove a voxel in response to the characteristics of the image areas corresponding to that

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voxel being inconsistent thereby producing a smaller voxel volume;

(g) to access data representing a second set of images consisting of a sub-set of the first set and a
5 further image of the object recorded at a different camera position from the first set of images;

(h) to determine, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each of the second set of
10 images;

(i) to compare the characteristics of the image areas in each of the second set of images;

(j) to remove a voxel in response to an inconsistency in the characteristics compared at step
15 (i), thereby producing a smaller voxel space; and

(l) to store the resulting voxel space as an updated representation of the three-dimensional object surface.

20 80. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and using the images and the camera positions to generate the
25 three-dimensional computer model, a method of processing

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the image data to derive a representation of a three-dimensional surface of the object, the method comprising the steps of:

(a) defining an initial volume containing the
5 object surface as an initial space formed of voxels;

(b) accessing data representing images of the object recorded at different camera positions with respect to the object;

(c) checking to see if a voxel meets at least one
10 criterion by projecting that voxel into at least one of the images;

(d) if the voxel does not meet said at least one criterion, dividing the voxel into subsidiary voxels; and

(e) then checking to see if the subsidiary voxels
15 meets at least one criterion by projecting the subsidiary voxels into at least one of the images.

81. In an image processing system for processing image data defining images of an object to generate a three-
20 dimensional computer model of the object by determining camera positions at which the images were recorded and using the images and the camera positions to generate the three-dimensional computer model, a method of processing the image data to derive a representation of a three-

dimensional surface of the object, the method comprising the steps of:

(a) defining an initial volume containing the object surface as an initial space formed of voxels;

5 (b) accessing data representing images of the object recorded at different camera positions with respect to the object;

(c) determining the area corresponding to a given voxel in each image in which the voxel is visible;

10 (d) comparing characteristics of each of the image areas corresponding to the given voxel;

(e) deriving from the compared characteristics a value representing the degree of any inconsistency between the characteristics of the image areas
15 corresponding to the given voxel;

(f) sub-dividing a voxel into subsidiary voxels in response to the derived value exceeding a threshold value and repeating steps (c) to (e) for each subsidiary voxel;

(g) in response to a subsidiary voxel having a
20 derived value exceeding a threshold value and a size greater than a minimum size, sub-dividing that subsidiary voxel into subsidiary voxels and repeating steps (c) to (e) for each subsidiary voxel of that subsidiary voxel;

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(h) removing any subsidiary voxel of the minimum size having a derived value exceeding the threshold value; and

5 (i) repeating steps (c) to (h) for each voxel that is not occluded by another voxel to provide a representation of the three-dimensional object surface consisting of the remaining non-occluded voxels and subsidiary voxels.

10 82. In a method of processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and using the images and the camera positions at which the images were recorded
15 and using the images and the camera positions to generate the three-dimensional computer model, an improvement comprising processing the image data to derive a computer representation of a three-dimensional surface of the object by:

20 (a) defining an initial volume containing the object surface as an initial space formed of voxels;

(b) accessing data representing images of the object recorded at different camera positions with respect to the object;

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(c) determining the area corresponding to a given voxel in each image in which that voxel is visible.

83. In a method of processing image data defining images
5 of an object to generate a three-dimensional computer
model of the object by determining camera positions at
which the images were recorded and using the images and
the camera positions to generate the three-dimensional
computer model, an improvement comprising processing the
10 image data to derive a computer representation of a
three-dimensional surface of the object by:

(a) defining an initial volume containing the
object surface as an initial space formed of voxels;

(b) accessing data representing images of the
15 object recorded at different camera positions with
respect to the object;

(c) determining the area corresponding to a given
voxel in each image in which the voxel is visible;

(d) comparing characteristics of each of the image
20 areas corresponding to the given voxel;

(e) deriving from the compared characteristics a
value representing the degree of any inconsistency
between the characteristics of the image areas
corresponding to the given voxel;

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(f) sub-dividing a voxel into subsidiary voxels in response to the derived value exceeding a threshold value and repeating steps (c) to (e) for each subsidiary voxel;

(g) in response to a subsidiary voxel having a
5 derived value exceeding a threshold value and a size greater than a minimum size, sub-dividing that subsidiary voxel into subsidiary voxels and repeating steps (c) to (e) for each subsidiary voxel of that subsidiary voxel;

(h) removing any subsidiary voxel of the minimum
10 size having a derived value exceeding the threshold value; and

(i) repeating steps (c) to (h) for each voxel that is not occluded by another voxel to provide a representation of the three-dimensional object surface
15 consisting of the remaining non-occluded voxels and subsidiary voxels.

84. In a method of processing image data defining images of an object to generate a three-dimensional computer
20 model of the object by determining camera positions at which the images were recorded and using the images and the camera positions at which the images were recorded and using the images and the camera positions to generate the three-dimensional computer model, a method for
25 processing the image data to derive a computer

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representation of a three-dimensional surface of the object by:

(a) defining an initial volume containing the object surface as an initial space formed of voxels;

5 (b) accessing data representing images of the object recorded at different camera positions with respect to the object;

(c) determining the area corresponding to a given voxel in each image in which that voxel is visible;

10 (d) comparing characteristics of each of the image areas corresponding to the given voxel;

(e) deriving from the compared characteristics a value representing the degree of any inconsistency between the characteristics of the image areas
15 corresponding to the given voxel;

(f) sub-dividing a voxel into subsidiary voxels in response to the derived value exceeding a threshold value and repeating steps (c) to (e) for each subsidiary voxel;

(g) removing any subsidiary voxel having a derived
20 value exceeding a threshold value; and

(h) repeating steps (c) to (g) for each voxel that is not occluded by another voxel to provide a representation of the three-dimensional object surface consisting of the remaining non-occluded voxels and
25 subsidiary voxels.

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- (a) defining an initial volume containing the
10 object surface as an initial space formed of voxels;
- (b) accessing data representing images of the
object recorded at different camera positions with
respect to the object;
- (c) determining the area corresponding to a given
15 voxel in each image in which the voxel is visible;
- (d) comparing characteristics of each of the image
areas corresponding to the given voxel;
- (e) deriving from the compared characteristics a
value representing the degree of any inconsistency
20 between the characteristics of the image areas
corresponding to the given voxel;
- (f) sub-dividing a voxel into subsidiary voxels in
response to the derived value exceeding a threshold value
and repeating steps (c) to (e) for each subsidiary voxel;
- 25 (g) in response to a subsidiary voxel having a

derived value exceeding a threshold value and a size greater than a minimum size, sub-dividing that subsidiary voxel into subsidiary voxels and repeating steps (c) to (e) for each subsidiary voxel of that subsidiary voxel;

5 (h) removing any subsidiary voxel of the minimum size having a derived value exceeding the threshold value; and

10 (i) repeating steps (c) to (h) for each voxel that is not occluded by another voxel to provide a representation of the three-dimensional object surface consisting of the remaining non-occluded voxels and subsidiary voxels.

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86. In an image processing system for processing image
15 data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and by using the images and the camera positions to generate the three-dimensional computer model, apparatus for
20 processing image data representing images of an object taken from a plurality of different camera positions to derive a representation of a three-dimensional surface of the object, the apparatus comprising a processor configured by processor instructions to operate:

(a) to define an initial volume containing the object surface as an initial space formed of voxels;

(b) to access data representing images of the object recorded at different camera positions with respect to the object;

(c) to check to see if a voxel meets at least one criterion by projecting that voxel into at least one of the images;

(d) if the voxel does not meet said at least one criterion, to divide the voxel into subsidiary voxels; and

(e) then to check to see if the subsidiary voxels meets at least one criterion by projecting the subsidiary voxels into at least one of the images.

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87. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and by using the images and the camera positions to generate the three-dimensional computer model, apparatus for processing image data representing images of an object taken from a plurality of different camera positions to derive a representation of a three-dimensional surface of

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the object, the apparatus comprising a processor configured by processor instructions:

(a) to define an initial volume containing the object surface as an initial space formed of voxels;

5 (b) to access data representing images of the object recorded at different camera positions with respect to the object;

(c) to determine the area corresponding to a given voxel in each image in which the voxel is visible;

10 (d) to compare characteristics of each of the image areas corresponding to the given voxel;

(e) to derive from the compared characteristics a value representing the degree of any inconsistency between the characteristics of the image areas
15 corresponding to the given voxel;

(f) to sub-divide a voxel into subsidiary voxels in response to the derived value exceeding a threshold value and repeating steps (c) to (e) for each subsidiary voxel;

(g) in response to a subsidiary voxel having a
20 derived value exceeding a threshold value and a size greater than a minimum size, to sub-divide that subsidiary voxel into subsidiary voxels and to repeat steps (c) to (e) for each subsidiary voxel of that subsidiary voxel;

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(h) to remove any subsidiary voxel of the minimum size having a derived value exceeding the threshold value; and

(i) to repeat steps (c) to (h) for each voxel that
5 is not occluded by another voxel to provide a representation of the three-dimensional object surface consisting of the remaining non-occluded voxels and subsidiary voxels.

10 88. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and by
15 using the images and the camera positions to generate the three-dimensional computer model, an improvement comprising apparatus for processing image data representing images of an object taken from a plurality of different camera positions to derive a representation
20 of a three-dimensional surface of the object, the apparatus comprising a processor configured by processor instructions to operate:

(a) to define an initial volume containing the object surface as an initial space formed of voxels;

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(b) to access data representing images of the object recorded at different camera positions with respect to the object;

(c) to determine the area corresponding to a given voxel in each image in which that voxel is visible;

(d) to compare characteristics of each of the image areas corresponding to the given voxel;

(e) to derive from the compared characteristics a value representing the degree of any inconsistency between the characteristics of the image areas corresponding to the given voxel;

(f) to sub-divide a voxel into subsidiary voxels in response to the derived value exceeding a threshold value and to repeat steps (c) to (e) for each subsidiary voxel;

(g) to remove any subsidiary voxel having a derived value exceeding a threshold value; and

(h) to repeat steps (c) to (g) for each voxel that is not occluded by another voxel to provide a representation of the three-dimensional object surface consisting of the remaining non-occluded voxels and subsidiary voxels.

89. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining

camera positions at which the images were recorded and by using the images and the camera positions to generate the three-dimensional computer model, an improvement comprising apparatus for processing image data representing images of an object taken from a plurality of different camera positions to derive a representation of a three-dimensional surface of the object, the apparatus comprising a processor configured by processor instructions:

- 10 (a) to define an initial volume containing the object surface as an initial space formed of voxels;
- (b) to access data representing images of the object recorded at different camera positions with respect to the object;
- 15 (c) to determine the area corresponding to a given voxel in each image in which the voxel is visible;
- (d) to compare characteristics of each of the image areas corresponding to the given voxel;
- (e) to derive from the compared characteristics a value representing the degree of any inconsistency between the characteristics of the image areas corresponding to the given voxel;
- 20 (f) to sub-divide a voxel into subsidiary voxels in response to the derived value exceeding a threshold value
- 25 and repeating steps (c) to (e) for each subsidiary voxel;

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(g) in response to a subsidiary voxel having a derived value exceeding a threshold value and a size greater than a minimum size, to sub-divide that subsidiary voxel into subsidiary voxels and to repeat
5 steps (c) to (e) for each subsidiary voxel of that subsidiary voxel;

(h) to remove any subsidiary voxel of the minimum size having a derived value exceeding the threshold value; and

10 (i) to repeat steps (c) to (h) for each voxel that is not occluded by another voxel to provide a representation of the three-dimensional object surface consisting of the remaining non-occluded voxels and subsidiary voxels.

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90. In a method of processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and using the images and
20 camera positions to generate the three-dimensional computer model, an improvement comprising processing the image data to derive a computer representation of a three-dimensional surface of the object by:

(a) defining an initial volume containing the
25 object surface as an initial space formed of voxels;

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(b) accessing data representing images of the object recorded at different camera positions with respect to the object;

(c) determining the area corresponding to a given voxel in each image in which that voxel is visible;

(d) determining a colour space value for each pixel of each area where each colour space value encompasses a range of pixel colour values;

(e) comparing the colour space values for each of the image areas corresponding to the same voxel; and

(f) removing the voxel only if the image regions do not share at least one colour space value.

91. In a method of processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and using the images and camera positions to generate the three-dimensional computer model, an improvement comprising processing the image data to derive a computer representation of a three-dimensional surface of the object by:

(a) defining an initial volume containing the object surface as an initial space formed of voxels;

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(b) accessing data representing images of the object recorded at different camera positions with respect to the object;

(c) determining the area corresponding to a voxel
5 in each image in which that voxel is visible;

(d) comparing characteristics of each of the image areas corresponding to the same voxel;

(e) deriving from the compared characteristics a value representing the degree of any inconsistency
10 between the characteristics of the image areas corresponding to the voxel; and, when the derived value for a voxel exceeds a threshold value:

(i) sub-dividing the voxel into subsidiary voxels;

15 (ii) determining the region corresponding to each sub-voxel in each image in which that sub-voxel is visible;

(iii) comparing characteristics of the image regions; and

20 (iv) removing the voxel only if there is no set of regions which contains a region from each image and for which the characteristics correspond.

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92. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and by
5 using the images and the camera positions to generate the three-dimensional computer model, apparatus for processing the image data to derive a computer representation of a three-dimensional surface of the object, the apparatus comprising a processor configured
10 by processor instructions to operate:

(a) to define an initial volume containing the object surface as an initial space formed of voxels;

(b) to access data representing images of the object recorded at different camera positions with
15 respect to the object which data provides a colour value for each pixel of each image;

(c) to determine the area corresponding to a voxel in each image in which that voxel is visible;

(d) to determine a colour space value for each
20 pixel of each area where each colour space value encompasses a range of pixel colour values;

(e) to compare the colour space values for each of the image areas corresponding to the same voxel; and

to remove the voxel only if the image regions do not
25 share at least one colour space value.

10 by processor instructions to operate:

object surface as an initial space formed of voxels;

15 respect to the object;

in each image in which that voxel is visible;

areas corresponding to the same voxel;

20 (e) to derive from the compared characteristics a value representing the degree of any inconsistency between the characteristics of the image areas corresponding to the voxel; and, when the derived value for a voxel exceeds a threshold value:

(i) to sub-divide the voxel into subsidiary voxels;

(ii) to determine the region corresponding to each sub-voxel in each image in which that sub-voxel is visible;

(iii) to compare characteristics of the image regions; and

(iv) to remove the voxel only if there is no set of regions which contains a region from each image and for which the characteristics correspond.

94. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and by using the images and the camera positions to generate the three-dimensional computer model, an improvement comprising apparatus for processing the image data to derive a computer representation of a three-dimensional surface of the object, the apparatus comprising a processor configured by processor instructions to operate:

(a) to define an initial volume containing the object surface as an initial space formed of voxels;

(b) to access data representing images of the object recorded at different camera positions with respect to the object which data provides a colour value for each pixel of each image;

5 (c) to determine the area corresponding to a voxel in each image in which that voxel is visible;

(d) to determine a colour space value for each pixel of each area where each colour space value encompasses a range of pixel colour values;

10 (e) to compare the colour space values for each of the image areas corresponding to the same voxel; and

to remove the voxel only if the image regions do not share at least one colour space value.

15 95. In an image processing system for processing image data defining images of an object to generate a three-dimensional computer model of the object by determining camera positions at which the images were recorded and by using the images and the camera positions to generate the
20 three-dimensional computer model, an improvement comprising apparatus for processing the image data to derive a computer representation of a three-dimensional surface of the object, the apparatus comprising a processor configured by processor instructions to
25 operate:

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(a) to define an initial volume containing the object surface as an initial space formed of voxels;

(b) to access data representing images of the object recorded at different camera positions with respect to the object;

(c) to determine the area corresponding to a voxel in each image in which that voxel is visible;

(d) to compare characteristics of each of the image areas corresponding to the same voxel;

(e) to derive from the compared characteristics a value representing the degree of any inconsistency between the characteristics of the image areas corresponding to the voxel; and, when the derived value for a voxel exceeds a threshold value:

(i) to sub-divide the voxel into subsidiary voxels;

(ii) to determine the region corresponding to each sub-voxel in each image in which that sub-voxel is visible;

(iii) to compare characteristics of the image regions; and

(iv) to remove the voxel only if there is no set of regions which contains a region from each image and for which the characteristics correspond.

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96. An image processing apparatus for processing image data representing images of an object taken from a plurality of different camera positions, the apparatus comprising:

5 a viewing volume determiner for determining the viewing volume for each camera position;

 a bound volume determiner for determining the volume bounded by the intersection of the viewing volumes; and

 an initial space setter for setting the bounded
10 volume as an initial space for use in deriving a representation of a three-dimensional surface of the object using said images.

97. An image processing apparatus for processing image
15 data representing images of an object taken from a plurality of different camera positions to derive a representation of a three-dimensional surface of the object, the apparatus comprising:

 a viewing volume determiner for determining the
20 viewing volume for each camera position at which an image was taken;

 a bound volume determiner for determining the volume bounded by the intersection of the viewing volumes;

 a divider for dividing the bounded volume into
25 voxels to form an initial voxel space; and

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a processor operable:

(i) to determine, for a voxel that is not occluded by another voxel, the area corresponding to that voxel in each image in which that voxel is represented;

5 (ii) to compare characteristics of each of the image areas corresponding to the same voxel; and

(iii) to remove a voxel when the characteristics of the image areas corresponding to that voxel are inconsistent.

10

98. An image processing apparatus for processing image data representing images of an object taken from a plurality of different camera positions to derive a representation of a three-dimensional surface of the object, the apparatus comprising:

15

an initial volume determiner for defining an initial volume containing the object as an initial space formed of voxels, and

a processor operable:

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(i) to access data representing a first set of images of the object each recorded at a respective one of a number of different camera positions with respect to the object;

(ii) to determine, for each voxel of the voxel space
25 that is not occluded by another voxel, the area

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corresponding to that voxel in each image of the first set of images in which that voxel is visible;

(iii) to compare characteristics of each of the image areas corresponding to the same voxel to remove any voxel have inconsistent characteristics and to store the resulting voxel space as a representation of the three-dimensional object surface, together with the characteristic associated with each non-occluded voxel of the resulting voxel space;

(iv) then to access data representing a further image of the object recorded at a different camera position from the first set of images;

(v) to determine, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in the further image;

(vi) to compare the characteristic of the image area in the further image with the characteristic already associated with that voxel;

(vii) to remove any voxel for which the characteristic of the image area of the further image is inconsistent with that already associated with that voxel; and

(viii) to store the resulting voxel space as modified representation of the three-dimensional object surface.

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formed of voxels; and

a processor operable:

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areas corresponding to the same voxel;

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5 (vi) to determine, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image of the second set;

(viii) to remove any voxel having inconsistent characteristics in the second set of images to store the resulting voxel space as an updated representation of the three-dimensional object surface.

an initial volume definer for defining an initial volume containing the object surface as an initial space formed of voxels;

a data accessor for accessing data representing images of the object recorded at different camera positions with respect to the object; and

a processor operable:

5 (c) to check to see if a voxel meets at least one criterion by projecting that voxel into at least one of the images;

(d) if the voxel does not meet said at least one criterion, to divide the voxel into subsidiary voxels;
10 and

(e) then to check to see if the subsidiary voxels meets at least one criterion by projecting the subsidiary voxels into at least one of the images.

15 101. An image processing apparatus for processing image data representing images of an object taken from a plurality of different camera positions to derive a representation of a three-dimensional surface of the object, the apparatus comprising:

20 an initial volume definer for defining an initial volume containing the object surface as an initial space formed of voxels;

a data accessor for accessing data representing images of the object recorded at different camera
25 positions with respect to the object; and

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(i) to determine the area corresponding to a given voxel in each image in which the voxel is visible;

(iii) to derive from the compared characteristics a value representing the degree of any inconsistency between the characteristics of the image areas corresponding to the given voxel;

(v) in response to a subsidiary voxel having a derived value exceeding a threshold value and a size greater than a minimum size, to sub-divide that subsidiary voxel into subsidiary voxels and to repeat (i) to (iii) for each subsidiary voxel of that subsidiary voxel;

(vii) to repeat (i) to (vi) for each voxel that is not occluded by another voxel to provide a representation

of the three-dimensional object surface consisting of the remaining non-occluded voxels and subsidiary voxels.

102. An image processing apparatus for processing image
5 data representing images of an object taken from a plurality of different camera positions to derive a representation of a three-dimensional surface of the object, the apparatus comprising:

an initial volume definer for defining an initial
10 volume containing the object surface as an initial space formed of voxels;

a data accessor for accessing data representing
images of the object recorded at different camera
positions with respect to the object which data provides
15 a colour value for each pixel of each image; and

a processor operable:

(a) to determine the area corresponding to a voxel
in each image in which that voxel is visible;

(b) to determine a colour space value for each
20 pixel of each area where each colour space value encompasses a range of pixel colour values;

(c) to compare the colour space values for each of
the image areas corresponding to the same voxel; and

(d) to remove the voxel only if the image areas do
25 not share at least one colour space value.

103. An image processing apparatus for processing image data representing images of an object taken from a plurality of different camera positions, a method of processing image data to derive a representation of a three-dimensional surface of the object, the apparatus comprising:

an initial volume definer for defining an initial volume containing the object surface as an initial space formed of voxels;

10 a data accessor for accessing data representing images of the object recorded at different camera positions with respect to the object; and

a processor operable:

15 (a) to determine the area corresponding to a voxel in each image in which that voxel is visible;

(b) to compare characteristics of each of the image areas corresponding to the same voxel; and

20 (c) to derive from the compared characteristics a value representing the degree of any inconsistency between the characteristics of the image areas corresponding to the voxel and, when the derived value for a voxel exceeds a threshold value,

(i) to sub-divide the voxel into subsidiary voxels,

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(ii) to determine the region corresponding to each sub-voxel in each image in which that sub-voxel is visible,

(iii) to compare characteristics of the image regions, and

(iv) to remove the voxel only if there is no set of regions which contains a region from each image and for which the characteristics are not inconsistent.

10 104. Apparatus according to claim 41, wherein the processor means is operable to determine, for each voxel of the voxel space that is not occluded by another voxel, the area corresponding to that voxel in each image in which that voxel is represented or visible by projecting
15 the voxel into the image.

105. Apparatus according to claim 41, wherein the processor means is operable to compare characteristics of each of the image areas corresponding to the same voxel
20 by comparing the colours of each of the image areas.

106. Apparatus according to claim 45, wherein the processor means is operable to compare characteristics of each of the image areas corresponding to the same voxel
25 by comparing the colours of each of the image areas.

107. Apparatus according to claim 49, wherein the processor means is operable to compare characteristics of each of the image areas corresponding to the same voxel by comparing the colours of each of the image areas.

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108. Apparatus according to claim 51, wherein the processor means is operable to compare characteristics of each of the image areas corresponding to the same voxel by comparing the colours of each of the image areas.

10

109. A method according to claim 72, further comprising, before step (g), a step (f) of repeating steps (c) to (e) until all non-occluded voxels having inconsistent characteristics have been removed and storing the resulting voxel space as a representation of the three-dimensional object surface, together with the characteristic associated with each non-occluded voxel of the resulting voxel space; and after step (j) a step (k) of repeating steps (h) to (j) until all non-occluded voxels having inconsistent characteristics have been removed and storing the resulting voxel space as an updated representation of the three-dimensional object surface.

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110. A method according to claim 73, further, comprising,
before step (g), a step (f) of repeating steps (c) to (e)
until all non-occluded voxels having inconsistent
characteristics have been removed and storing the
5 resulting voxel space as a representation of the three-
dimensional object surface, together with the
characteristic associated with each non-occluded voxel of
the resulting voxel space; and after step (j) a step (k)
of repeating steps (h) to (j) until all non-occluded
10 voxels having inconsistent characteristics have been
removed and storing the resulting voxel space as an
updated representation of the three-dimensional object
surface.
111. A method according to claim 74, further comprising,
before step (g), a step (f) of repeating steps (c) to (e)
until all non-occluded voxels having inconsistent
characteristics have been removed and storing the
15 resulting voxel space as a representation of the three-
dimensional object surface, together with the
characteristic associated with each non-occluded voxel of
the resulting voxel space; and after step (j) a step (k)
of repeating steps (h) to (j) until all non-occluded
20 voxels having inconsistent characteristics have been
removed and storing the resulting voxel space as an
25

updated representation of the three-dimensional object surface.

112. A method according to claim 75, further comprising,
5 before step (g), a step (f) of repeating steps (c) to (e)
until all non-occluded voxels having inconsistent
characteristics have been removed and storing the
resulting voxel space as a representation of the three-
dimensional object surface, together with the
10 characteristic associated with each non-occluded voxel of
the resulting voxel space; and after step (j) a step (k)
of repeating steps (h) to (j) until all non-occluded
voxels having inconsistent characteristics have been
removed and storing the resulting voxel space as an
15 updated representation of the three-dimensional object
surface.

113. Apparatus according to claim 76, wherein the
processor is operable to:

20 (f) repeat steps (c) to (e) until all non-occluded
voxels having inconsistent characteristics have been
removed and storing the resulting voxel space as a
representation of the three-dimensional object surface,
together with the characteristic associated with each
25 non-occluded voxel of the resulting voxel space; and

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114. Apparatus according to claim 77, wherein the processor is operable to:

(k) repeat steps (h) to (j) until all non-occluded voxels having inconsistent characteristics have been removed.

(f) repeat steps (c) to (e) until all non-occluded
20 voxels having inconsistent characteristics have been
removed and store the resulting voxel space as a
representation of the three-dimensional object surface,
together with the characteristic associated with each
non-occluded voxel of the resulting voxel space; and

(k) repeat steps (h) to (j) until all non-occluded voxels having inconsistent characteristics have been removed.

5 116. Apparatus according to claim 79, wherein the processor is operable to:

(f) repeat steps (c) to (e) until all non-occluded voxels having inconsistent characteristics have been removed and store the resulting voxel space as a representation of the three-dimensional object surface,
10 together with the characteristic associated with each non-occluded voxel of the resulting voxel space; and

(k) repeat steps (h) to (j) until all non-occluded voxels having inconsistent characteristics have been
15 removed.

117. A method of operating an image processing apparatus for processing image data representing images of an object taken from a plurality of different camera
20 positions, the method comprising the steps of:

(a) determining the viewing cone for each camera position;

(b) determining the volume bounded by the intersection of the viewing cones; and

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(c) setting the bounded volume as an initial space for use in deriving a representation of a three-dimensional surface of the object using said images.

- 5 118. An image processing apparatus for processing image data representing images of an object taken from a plurality of different camera positions, the apparatus comprising:

10 means for determining the viewing cone for each camera position;

means for determining the volume bounded by the intersection of the viewing cones; and

15 means for setting the bounded volume as an initial space for use in deriving a representation of a three-dimensional surface of the object using said images.

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